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Conservation Effects Assessment Using SWAT in Cheney Lake Watershed CEAP South-central Kansas

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***Abstract*.** Several best management practices (BMPs) have been implemented to protect and improve water quality benefits in the Cheney Lake watershed (CLW). Although, implementation of BMPs has been documented in the CLW, quantification of spatially varied water quality benefits over the time is limited. The objectives of this study were to evaluate effectiveness of BMPs (agricultural waste, repair failing septic systems, and conservation reserve program - CRP) implemented in the CLW (1995-2006) to reduce flow, sediment yield, and total phosphorus transport to the various reaches of the CLW using Soil and Water Assessment Tool (SWAT).

The SWAT model confirmed a results of good to fair correlation and agreement (R^2 = 0.57-0.61, NSE = 0.35-0.54) for flow, sediment yield, and total phosphorus when verified at North Fork of Ninnescah using monthly USGS data. Model results demonstrated that agricultural waste and repair failing septic systems BMPs reduced total phosphorus loss by 1 to 6 %, depending on spatial and temporal variability of the selected watershed reach. Increasing the CRP land by only 4.7 % reduced monthly flow (1.8 to 2 %), sediment yield (3 to 13 %), and total phosphorus (5.3 to 10.3 %). Of the three BMPs evaluated, conversion of crop land to CRP was the most effective for reduction of sediment and total phosphorus loads in the watershed. The SWAT model successfully evaluated historical BMPs implementation in this watershed.

Keywords. *BMPs, flow, sediment, total phosphorus, SWAT*.

Introduction

Agricultural activities are one of the major sources of deteriorating surface and ground water resources in the United States. Surface runoff carries sediment, organic matter, and nutrients. Nutrients, primarily phosphorus, could be a major problem because they can cause eutrophication due to algae growth, which may reduce oxygen availability and increase turbidity in water bodies. Several best management practices (BMPs) have been implemented to protect and improve water quality benefits in the Cheney Lake watershed (CLW). Although, there are documented indications on implementation of numbers of BMPs in the watershed, quantification of the effects of spatially varied climate, soils, land management conditions and BMPs across the watershed over time on water quality is limited. The effectiveness of BMPs for livestock systems, which utilize pastureland for grazing and cropland or pastureland for manure waste disposal have not been adequately demonstrated. It is important to determine the effectiveness of BMPs to ensure more effective use of resources and minimize adverse impacts on water quality. Field monitoring and field experiments for each combination of BMPs are difficult at watershed scale. A watershed modeling approach considers spatial and temporal variations of BMPs and quantifies their effect across the watershed on water quality. Quantifying water quality benefits of BMPs will allow policy-makers and watershed program managers to evaluate the benefits of the existing BMP programs and to design new BMP programs that more effectively and efficiently meet the water quality goals (Mausbach and Dedrick, 2004).

The SWAT water quality model has been applied for one or more pollutant parameters such as runoff, sediment yield, and nutrient losses from watersheds at different geographic locations, conditions, and management practices (Gassman et al., 2007; Jha et al., 2007; Kirsch et al., 2002; Qi and Grunwald, 2005; Saleh et al., 1999; Santhi et al., 2001; Spruill et al., 2000; Van Liew et al., 2003; Wang et al., 2006; White et al., 2004; White and Chaubey, 2005). Several previous studies evaluated effectiveness of BMPs on water quality, which can be directly modeled changing input parameters in the SWAT model such as P-factor for considering terracing, contouring, and strip cropping; channel cover factor or channel erodibility factors for grassed waterways; channel slope and channel erodibility factor for grade stabilization structure; filter widths for field border; slope lengths, P-factor, and curve number factor for parallel terrace; tillage changes for tillage practices (Arabi et al., 2007; Bosch et al., 2005; Bracmort et al., 2004; Bracmort et al., 2006; Chu et al., 2005; Gitau et al., 2004).

Limited research has been performed using the SWAT (2005) model for evaluating BMPs effectiveness, particularly agricultural waste (NRCS codes 312, 313), repair failing septic systems, and increasing CRP land areas by reducing cropland areas with the objectives of reducing pollutants transport to the watershed outlet. These types of BMPs modeling can not be directly input in SWAT, but required methods that consider a variety of source load related inputs in the model. Parajuli et al. (2008) calibrated SWAT model mainly using curve numbers in the Red Rock Creek watershed and validated SWAT model in the Goose Creek watershed both sub-watersheds of the Cheney Lake watershed. Further verification of the SWAT model is needed at large scale. In this study, SWAT model simulations were performed to assess three of BMPs that have potential impact on reducing flow, sediment and phosphorus loss in the CLW. This study utilized BMP data documented from cost-share contracts and field surveys during 1995 to 2006 (Nelson et al., 2007).

The overall objectives of this research were to describe methods to evaluate spatially varied BMPs implemented in the CLW over time. The two specific objectives of this study were: (a) evaluate effectiveness of BMPs implementation on water quality (flow, sediment, total phosphorus) at watershed scale, (b) Identify the BMP that resulted in the greatest water quality improvement.

Methods and Materials

Study Area

The Cheney Lake watershed (Fig. 1) is located in Reno, Pratt, Kiowa, Kingman, Stafford and Edwards counties in south-central Kansas, which consists of 2561 km^2 with average elevation of 530 m. It is an agricultural watershed consisting of cropland (54%), grassland (21%), CRP land (19%), woodland (4%), waters and urban areas (2%). Watershed soils are predominantly course/fine loamy textures (SSURGO stmuid: KS 1555996, KS1515902, KS 1515944, KS 1855944, KS 1556348, and KS 1555960). Primary crops are wheat, grain sorghum, corn, and soybean. The city of Wichita, Kansas uses Cheney Lake as a primary water supply for over 350,000 residents. The CLW has been a focus watershed for multiple water quality related research, extension, and education programs since the early 1990s.

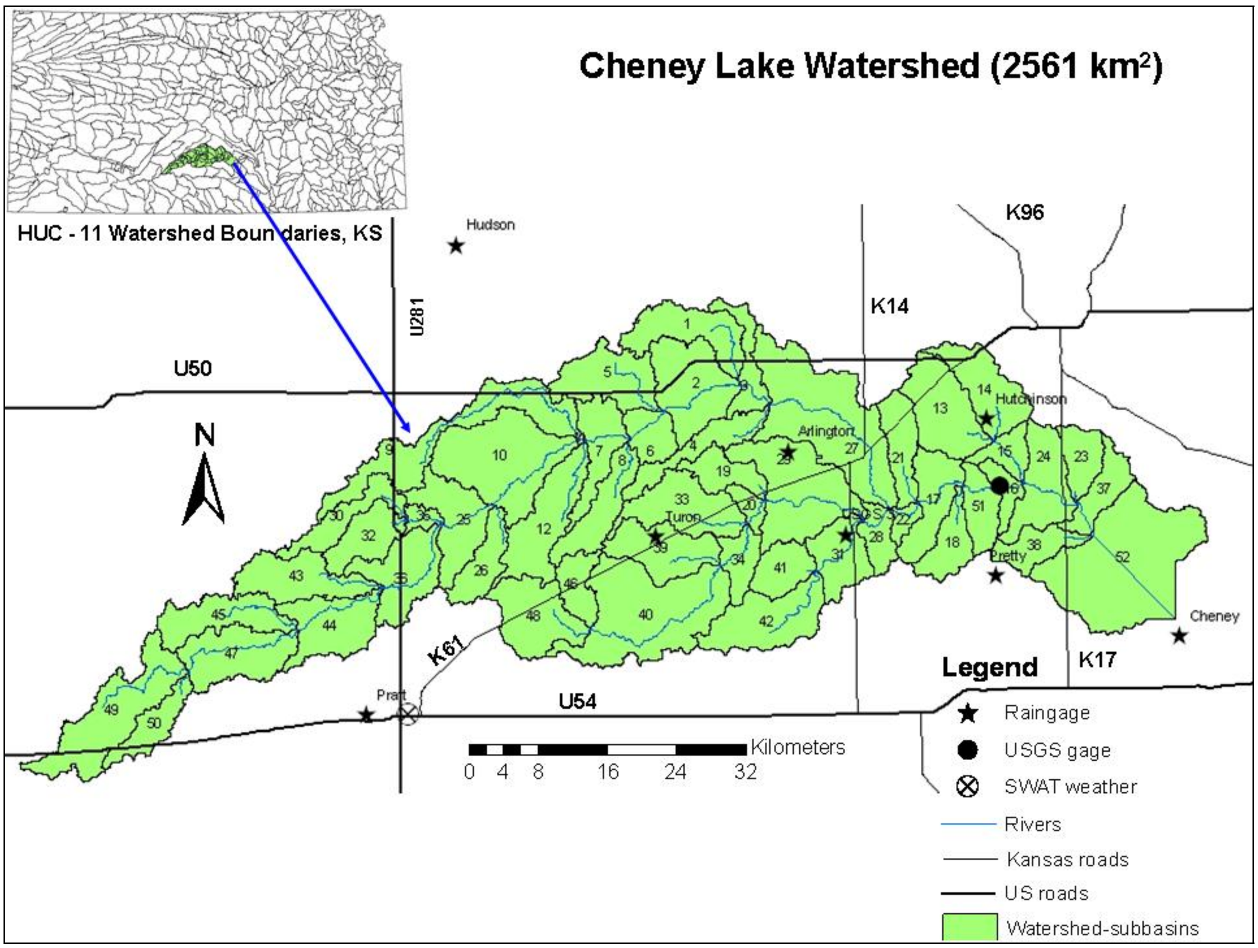

Figure 1. Location of the Cheney Lake watershed in south-central Kansas

Pollutant Sources

In addition to runoff from crop production fields, non-point source pollution can originate from several other sources. Livestock and household waste systems (septic system) were two major pollutant sources identified in the watershed. Specifically identified pollutant sources were: livestock in the pastureland during summer, livestock in the permitted and non-permitted animal feeding operations, livestock with or with-out animal waste BMPs, and failing septic systems in the watershed. Pollutant sources change spatially and temporally throughout the watershed.

Livestock

The number of animal units (AUs) in the confined animal feeding operations (CAFO) within the watershed were estimated using active CAFOs data (both federally permitted feedlots > 1000 AUs and state registered feedlots > 300 AUs) from the Kansas Department of Health and Environment (KDHE) (Robert Gavin, 2008, personal communication). Permitted CAFOs were verified using field survey data for the CLW. Additional data on all non-permitted animal feeding operations was collected; including the number of days livestock spend in the feedlots and pasturelands (Howard Miller, 2007, personal communication). The field reported stocking rate of about 4 ha per cow and calf pair (KDA, 2004) was used as the baseline value, but could vary due to pasture management activities, animal growth and animal sales in the watershed. Animals in the pasturelands could be brought from feedlots, barnyards and leasing agreements for grazing during the warm season (generally from April to September). However, the stocking rate of the animals in the pastureland was assumed to be constant throughout the grazing season.

The estimated animal population in Cheney Lake is 13,445 beef AUs in the pastureland (based on stocking rate), and 25,009 AUs (beef, dairy, swine, goats, sheep, horse) in the feedlots. About 49% of feedlot AUs reside in the lot year-round (365 days), which were considered in this study to represent the current scenario of the watershed. Livestock in the pastureland may access in the stream where no fencing is installed near the streams. It was assumed that the livestock access to the stream for about 30 minutes per day (J. Harner, personal communication, 2006). Manure production by beef cattle was estimated based on standard production rates (ASAE, 2000), of 58-kg of wet manure per day per 1000-kg AU. The actual manure production by each AU may vary depending on dietary habit of the animal, reflected in a reported standard deviation of 17 kg per day for manure estimation (ASAE, 2000). Total phosphorus production in beef manure was estimated based on ASAE (2000), which reported 0.09 kg per day per AU wet-weight-basis. The total manure and phosphorus production was converted into model-input units of kg per day of dry-weight manure using standard mean manure moisture content (86% moisture; ASAE, 2000).

The grassland landuse was simulated under grazed condition. It was estimated that about 20% of the air-dry biomass is trampled every day, and about 341 kg of air-dry forage is required for an AU for 30 days (Paul and Watson, 1994). The biomass was not removed from the CRP lands. Since cattle do not graze pastureland from October to March, no biomass uptake from the pastureland occurred, with no grass trampling and no manure deposition on the soil during this period.

There are 96 CAFOs (Table 1) located in the CLW, 16 of which implemented agricultural waste BMPs (NRCS code 312, 313) during 1995-2004. The CAFOs that implemented agricultural waste BMPs are located in sub-basins 14(11), 27(1), 39(1), 40(1), 51(1), and 52(1). The main difference between modeling CAFOs with BMPs vs. those without BMPs are: (i) for CAFOs with BMPs, animal manure is collected, which is not subject to runoff, and land-applied in the cropland, (ii) for CAFOs without BMPs, animal manure is deposited/applied or piled everyday in the confined area during animals days in lot, which is subject to runoff, then subsequently land-applied in the cropland. All source loads due to livestock in CAFOs with or without agricultural waste BMPs were considered to be land-applied (wet weight of manure about 26 Mg ha^{-1} yr^{-1}) in the cropland areas of the selected HRUs (0.11 - 3.74 km^2) in the sub-watershed where active permitted feedlots were located. All source loads due to livestock in CAFOs without agricultural waste BMPs were estimated for animal days in lots and considered daily land-applied in the cropland areas of the selected HRUs.

Table 1. Livestock days in lots and best management practices (BMPs) conversion years in the watershed

Sub-basin	Type	AUs	Days in lots	Conv. year	Sub-basin	Type	AUs	Days in lots	Conv. year
1	beef	100	120		24	beef	50	90	
2	beef	80	120		24	beef	76	120	
2	beef	200	65		24	beef	121	120	
4	swine	37	365		24	sheep	250	270	
4	beef	150	180		24	horse	34	365	
6	goats	50	365		25	beef	800	365	
9	beef	50	120		25	beef	25	90	
9	beef	30	90		27	dairy	700	190	2006
9	beef	300	180		27	beef	325	300	
9	beef	375	180		27	beef	125	200	
10	beef	42	65		27	beef	200	120	
10	beef	500	365		27	beef	90	95	
13	beef	30	150		27	beef	70	365	
13	beef	17	365		27	beef	150	365	
13	beef	26	120		27	beef	50	60	
13	beef	48	180		28	beef	250	145	
14	dairy	84	365	1998	28	beef	300	180	
14	dairy	168	365		29	beef	350	120	
14	dairy	112	365	2001	29	beef	150	120	
14	dairy	98	245	1999	29	beef	150	120	
14	dairy	140	90	2002	29	beef	125	145	
14	dairy	42	45	1995	29	beef	150	90	
14	dairy	112	300	1999	30	beef	200	180	
14	dairy	119	365		30	beef	900	180	
14	dairy	98	305	2001	33	beef	3500	365	
14	beef	280	45	1997	36	beef	3000	365	
14	beef	70	365	1996	36	beef	900	365	
14	dairy	222	345		39	beef	500	365	2004
14	dairy	140	45	1997	40	beef	950	300	2000
14	dairy	140	30		40	beef	600	300	
14	dairy	140	180	1999	42	beef	500	365	
14	dairy	133	265		48	beef	175	120	
14	beef	30	90		50	beef	999	120	
15	beef	30	120		51	dairy	84	40	1995
15	beef	18	365		51	beef	17	90	
16	beef	22	180		51	beef	20	120	
17	beef	100	90		52	dairy	336	365	1997
17	beef	300	90		52	beef	150	365	
17	beef	37	90		52	beef	400	120	
19	beef	225	60		52	dairy	98	30	
21	swine	480	365		52	beef	300	120	
21	swine	600	365		52	beef	350	120	
21	beef	15	90		52	beef	30	200	
23	beef	15	180		52	beef & horse	35	365	
23	beef	52	120		52	beef	28	365	
23	beef	27	180		52	beef	20	90	
23	beef	74	180		52	beef	18	120	
24	beef	150	90		52	beef	50	180	

Household Waste Systems (Septic)

The topographically integrated geographic encoding and referencing (TIGER) data for the watershed were utilized to estimate number of rural households in the watershed. Each rural house was assumed to have one septic system, resulting in a total of 1215 septic systems in the watershed. About 30% of the estimated septic systems (or 367 septic systems) were estimated failing in the watershed (French L., 2008, personal communication) as baseline condition. The State of Kansas has an average of 40% failing septic systems through out the State (KDHE, 2000). Each septic system was assumed to be used by three persons in the household, contributing about 0.32 m^3 of sewage effluent per household per day (US EPA, 2001). Water quality impacts of failing septic systems were simulated by land-applying 90% of the effluent (which was then subject to runoff and erosion loss) and inputing the remaining 10% of the effluent as a direct-daily point load to the outlet of the each sub-basin (Table 2). Humans generate 3.28 g phosphorus per capita per day in domestic waste water (Crites and Tchobanoglous, 1998; McCray et al., 2005). Repair of failing septic systems is one of the top three BMP implemented in the CLW from 1995 to 2006 (based on the number of cost-share contracts). Repair of failing septic systems around the watershed was spatially variable over time.

Table 2. Failing septic systems and their repair years as BMP in the Cheney Lake watershed

Sub-basin	Failing septic	Repair year (number)	Sub-basin	Failing septic	Repair year (number)
1	8	04(1)	27	30	05(1), 06(1)
2	8	0	28	2	0
3	4	0	29	11	03(2), 06(1)
4	4	98(1)	30	2	96(1), 00(1)
5	4	0	31	6	98(1), 04(1), 06(1)
6	1	0	32	3	96(1), 98(1), 99(1), 04(2)*
7	4	04(1), 06(2)	33	6	0
8	2	99(1)	34	3	0
9	16	0	35	1	04(1), 05(1)*
10	6	0	36	6	99(1), 03(1), 04(1)
11	0	0	37	4	98(1)
12	6	96(1), 97(1), 04(1)	38	8	99(1), 00(1), 01(1)
13	14	97(2), 00(1), 03(1)	39	7	0
14	35	95(1), 99(1), 01(1)	40	8	96(1), 97(1), 01(1)
15	5	95(1), 99(1), 01(1)	41	4	01(1), 02(1), 04(2)
16	2	97(1), 02(1)	42	9	96(2), 97(2), 98(2), 99(2), 00(1), 01(1)*
17	5	02(1)	43	5	96(1), 97(1), 98(1), 99(1), 02(1)
18	5	0	44	4	99(1)
19	2	0	45	2	00(2)
20	3	0	46	2	96(2)
21	5	06(1)	47	2	0
22	1	0	48	5	98(1), 00(1), 03(2)
23	11	02(1)	49	8	0
24	15	97(2), 99(1), 02(1), 03(2), 06(1)	50	2	0
25	3	01(1)	51	5	0
26	5	96(1), 99(1), 00(1), 03(1), 05(1)	52	48	96(2), 98(3), 99(2), 00(2), 01(1), 04(1)

*Septic systems repaired more than once

Best Management Practices

Agricultural waste BMPs, repair failing septic systems, and converting cropland areas to CRP land areas were among the top BMPs implemented in the watershed. The BMP implementation was not equally distributed in the watershed. The majority of agricultural waste BMPs (11 out of 16) were implemented in sub-basin 14 (Table 1). Repair failing septic systems is one of the mostly commonly adopted BMPs in the watershed (Nelson et al., 2007). More septic system failures have been found in sub-basins 52, 14, and 27 than in rest of the watershed (Table 2). Although CRP land conversion process has been implemented before or after 1995, BMP records were only documented for 1997 and 2006, which estimated a net conversion of about 4.7% cropland areas to CRP during that time period, increasing from 19% to 24% CRP. The CRP land area increased in 40 sub-watersheds of CLW from 1997 to 2006.

SWAT Model

The SWAT model utilizes geospatially referenced data to satisfy the necessary input parameters. United State Geological Survey (USGS, 1999), 30m x 30m grid digital elevation data was used to delineate the watershed boundaries and topography. Soil Survey Geographic Database (SSURGO) was utilized to create a soil database (USDA, 2005). Land in the CRP covers about 19% of the watershed area. The CRP land was simulated with five typical grass species: little bluestem, big bluestem, indiangrass, side oats, and switchgrass. These five grasses have about equal cover in the watershed. Grassland, which might be harvested covers about 21% of the watershed area and typically includes rangeland big bluestem. The CRP grasses are generally not fertilized (Lisa French, Cheney Lake Watershed Inc., 2007, personal communication).

A majority (~54%) of the land use areas in the watershed are cropland. Grain sorghum and soybean are major warm-season crops, and winter wheat is a primary cool-season crop grown in a four-year rotation (Lisa French, Cheney Lake Watershed Inc., 2007, personal communication). Typical planting and harvesting dates are May 25 and October 20 for warm-season crops and October 20 and June 29 for cool-season crops. Crop residue is left on the ground between the crop periods. Sorghum, soybean, and wheat are cultivated primarily with conventional system. Primary herbicides used for warm-season crops are Bicep II Magnum for sorghum and Roundup for soybean; Finesse was used for winter wheat. Woodlands cover about 4% of the watershed land use area. Model default parameters were used for woodland areas assuming mixed forest trees in the watersheds.

Land use and land management were estimated by analyzing Landsat 5 satellite imagery using stacked images from May and August of 1997 for major crop types and unsupervised classification techniques within ArcView Image Analysis with ground truth verification using Farm Service Agency records. Image Analysis in ArcView also is capable of performing the Normalized Difference Tillage Index (NDTI) (band 5-band 7)/band 5+band 7) function using Landsat 5 mid-infrared bands 5 and 7. Once the NDTI function was completed, results were separated into three crop residue covers: high, medium and low. Using this information, paired with local knowledge, land use and management was classified into 24 classes with major land uses including wheat, soybean, grain sorghum, corn, CRP, forestland, pastureland, rangeland, urban land, and water (Lyle Frees, 1997, unpublished data).

The stream threshold area was defined as an equivalent area of 24.16 km^2, which is less than 1% of the total watershed area (2,561 km^2). The SWAT model delineated 52 sub-basins ranging from 0.65 km^2 to 166 km^2. The watershed parameters for each Hydrologic Response Unit (HRU) in each watershed were defined on the basis of soil, landuse, and topographic characteristics of the watershed as described in the SWAT documentation version 2005 (Neitsch et al., 2005).

Weather and Hydrologic Data

Weather data, such as daily precipitation and daily ambient temperatures, were extracted from the National Climatic Data Center (NCDC). The daily precipitation data were used from eight weather stations in or near the watershed: Arlington, Turon, Hudson, Hutchinson, Pretty, USGS gage 3, Pratt, and Cheney Lake (Fig. 1). The missing data were adjusted using SWAT database simulation. The SWAT model uses Pratt weather station, which is located about 8 kilometers south-west and Wichita weather station located about 36 kilometers south-east from the watershed. Annual rainfall from the weather stations used for inputs is displayed in Table 3.

Table 3. Annual precipitation records (mm) of the 8 weather stations for the watershed

Year	Arlington	Turon	Hudson	Hutchinson	Pretty Prairie	USGS 3	Pratt	Cheney
1995	573	700	-	847	-	-	-	-
1996	706	715	605	661	-	63	742	-
1997	766	830	829	819	-	711	880	-
1998	683	693	711	814	-	462	615	-
1999	639	667	758	780	-	600	718	-
2000	756	839	760	843	-	494	887	-
2001	845	505	646	584	-	-	352	-
2002	715	707	763	782	903	-	715	605
2003	498	625	617	735	746	-	635	815
2004	770	913	848	838	939	-	772	910
2005	714	745	733	818	872	-	641	901
2006	575	523	688	587	570	-	704	637
Average	***687***	***705***	***723***	***759***	***806***	***466***	***696***	***774***

Statistical Analysis

The SWAT model predictions for monthly flow, sediment yield, and total phosphorus were verified using twelve years of USGS measured data (January, 1995 to December, 2006). There were one hundred and forty-four months of measured data utilized in this study. The coefficient of determination (R^2) and Nash-Sutcliffe Efficiency Index (NSE) statistical parameters were used to compare measured and predicted mean monthly flow, sediment yield, and total phosphorus data to verify the SWAT model. The R^2 and NSE are also known as model correlation and agreement efficiencies parameters. As modified by Parajuli (2007) from Moriasi et al. (2007), the model efficiencies were classified as excellent ($E \geq 0.90$), very good ($E = 0.75$ to 0.89), good ($E = 0.50$ to 0.74), fair ($E = 0.25$ to 0.49), poor (0 to 0.24), and unsatisfactory (< 0).

Results and Discussion

The SWAT model responses to monthly flow, sediment, and total phosphorus transport were verified using USGS gage station data (1995-2006) at North Fork of Ninnescah (Fig. 1) for the model confirmation at the current condition, which considered top five BMPs. This study further verified the SWAT model in the Cheney Lake watershed using *esco* (0.50), which is a widely used calibrating factor for flow in the SWAT model. The esco is a soil evaporation compensation factor that allows model to modify depth distribution used to meet the soil evaporative demand to account for the effect of capillary action. As the value of esco is reduced, the model can extract more water from the lower levels to meet the evaporative demand. Several previous studies used esco as a calibration factor with the similar range (Choi et al., 2005; Parajuli, 2007; Santhi et al., 2001; Saleh and Du, 2004; White and Chaubey, 2005).

SWAT Model Verification

Flow

A verified SWAT model for the Cheney Lake watershed at North Fork of Ninnescah (USGS gage: 07144780) predicted mean monthly flow of the watershed with good correlation and good agreement ($R^2 = 0.61$, NSE = 0.54) between mean monthly measured and mean monthly predicted flow values (Fig. 2). Model correlation and agreement slightly decreased when SWAT was verified in the whole CLW as compared to the SWAT calibration ($R^2 = 0.81$, NSE = 0.56) in Red Rock Creek sub-watershed (Parajuli et al., 2008). This study utilized 12 years of weather data from eight different climate stations. The slight decrease in the coefficient of determination, and model efficiency were likely a result of the larger watershed area, with greater spatial variability, more weather stations, and greater spatial averaging from lumping landuse and soil characteristics. In a similar study, Parajuli (2007) verified SWAT model in Upper Wakarusa watershed (950 km^2) in Kansas after a successful calibration and validation of model in Rock Creek and Deer Creek sub-watersheds. Similar to results in this study, Parajuli (2007) found that R^2 and NSE values decreased (0.52 to 0.90) when the SWAT model was verified in the whole Upper Wakarusa watershed after calibration in Rock Creek sub-watershed. Three years of weather data were used from 5 different climate stations.

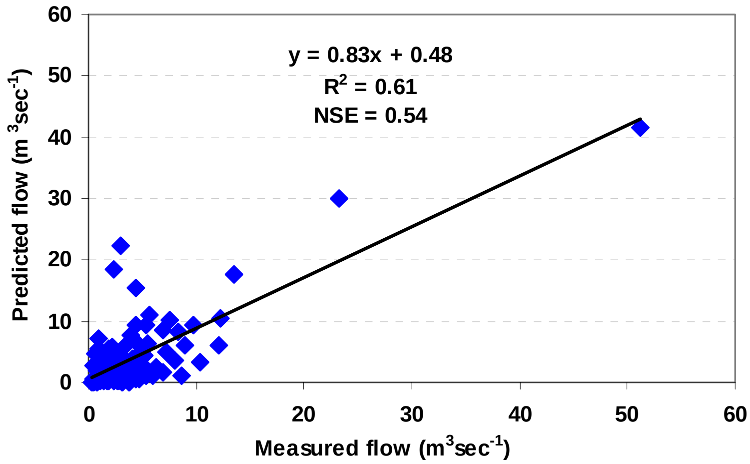

Figure 2. Measured vs. predicted monthly flow at North Fork of Ninnescah

Sediment Yield

There was good correlation and fair agreement (R^2 = 0.58, NSE = 0.35) between measured and predicted monthly sediment yield when SWAT was verified in the CLW (Fig. 3). The model under-predicted sediment yield (slope = 0.74) from the CLW. No further calibration for sediment yield was done. Comparing SWAT model results with other studies, model did good job predicting sediment yield in this watershed. Santhi et al. (2001) validated the SWAT model in the Bosque River watershed in Texas. The validated SWAT model performed with good to fair NSE values (0.70 to 0.23) for monthly sediment prediction when compared with measured data. Jha et al. (2007) applied the SWAT model in the Raccoon River watershed in Iowa and found that the SWAT model predicted sediment yield with good correlation and agreement (R^2 = 0.55, NSE = 0.53) during model calibration period. Both of these studies calibrated and validated SWAT model in the same watershed using different periods of measured data. Our study verified the previously calibrated and validated SWAT model in a watershed approximately 18 times larger than the watersheds used for calibration and validation, which differs from previous studies.

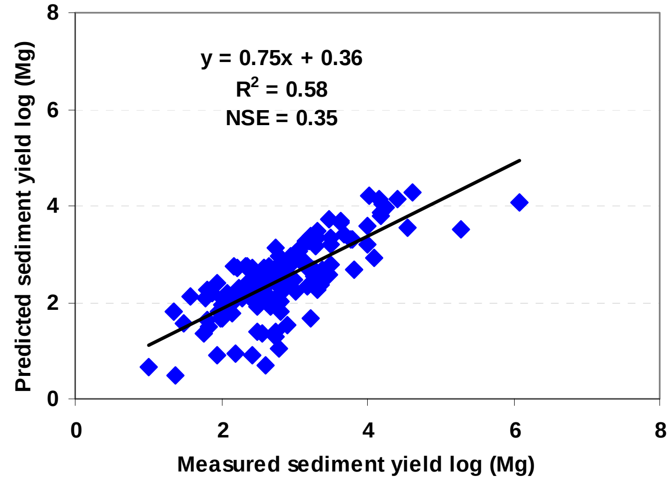

Figure 3. Measured vs. predicted monthly sediment yield at North Fork of Ninnescah

Total Phosphorus

The SWAT model resulted good correlation and fair agreement (R^2 = 0.57, NSE = 0.35) between predicted and mean monthly measured total phosphorus during model verification in the CLW (Fig. 4). Comparing SWAT results with other similar studies determined reasonable results. Santhi et al. (2001) calibrated and validated the SWAT model in the Bosque River watershed in Texas. The calibrated SWAT model showed good agreement with NSE values ranging from 0.53-0.70, for monthly mean total phosphorus compared with mean monthly measured data. The validated model had fair to good agreement, with NSE values ranging from 0.39-0.72, for mean monthly total phosphorus prediction compared with mean monthly measured data.

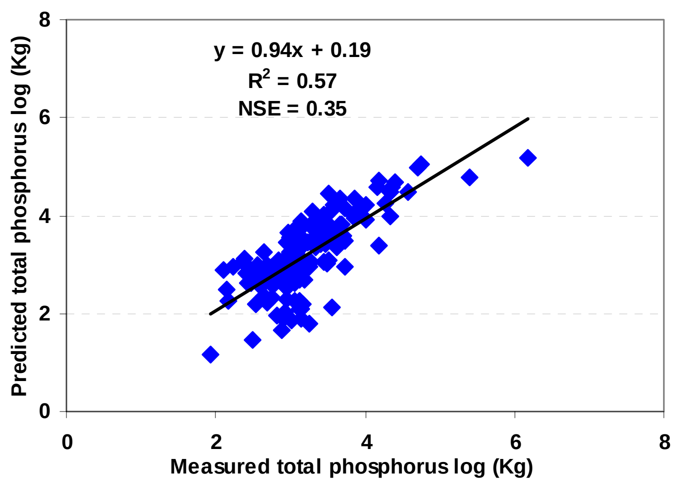

Figure 4. Measured vs. predicted monthly total phosphorus at North Fork of Ninnescah

Several other studies successfully calibrated and validated the SWAT model for monthly total phosphorus prediction (Saleh and Du, 2004; White and Chaubey, 2005; Arabi et al., 2006;

Bracmort et al., 2006; Cheng et al., 2006; Tolson and Shoemaker, 2007; Gassman et al. 2007). Our study verified SWAT in CLW using 12 years of monthly measured data, which still showed good correlation and allowed us to evaluate effects of various spatially varied BMPs implementation over the time.

Evaluation of Best Management Practices

Three of the top five BMPs, (i) agricultural waste BMPs, (ii) repair failing septic systems and (iii) conservation reserve program, were evaluated independently for their ability to reduce flow, sediment yield, and total phosphorus transport from the various outlets of the CLW. The predicted average monthly flow, sediment, and P loss for the base condition (no BMPs) and the predicted reductions resulting from BMP implementation presented in Table 4. Agricultural waste BMPs and repair of failing septic systems in the watershed generally did not effect predicted average monthly flow and sediment yield (0.08 – 1.8%) at the various watershed outlets. However, these two BMPs had noticeable effects in reducing total phosphorus from the baseline values (1 - 6%). An increase of CRP land area in the watershed was documented for 2006. The conversion of about 4.7 % of cropland areas to CRP land areas reduced predicted average monthly flow (1.8 - 2%), sediment yield (3 - 13%), and total phosphorus losses (5.3 - 10.3%). Davie and Lant (1994) studied the impact of CRP implementation on erosion rates in two Illinois watersheds. They reported that the CRP enrollments on 15% cropland decreased estimated erosion rates by 24% whereas increasing CRP enrollments to cover 27% of the cropland decreased the erosion rates by 37%.

Table 4. Soil and Water Assessment Tool model results for 12 years monthly average baseline and the % changes from the baseline for each scenario at various stations for selected indicators

Scenario	Flow (m^3s^{-1})	Sediment (Mg)	Total P (Kg)
Station: USGS			
Baseline	3.53	1,515	9,845
Percentage changes from baseline			
1. Agricultural waste	-0.37	-0.08	-4.84
2. Repair failing septic systems	-0.37	-0.11	-1.81
3. Conservation reserve program[a]	-1.93	-5.14	-5.29
Station: Lake inlet			
Baseline	4.26	2,293	19,669
Percentage changes from baseline			
1. Agricultural waste	-0.34	-1.86	-5.65
2. Repair failing septic systems	-0.34	-1.86	-1.14
3. Conservation reserve program[a]	-2.01	-12.6	-10.29

[a]Reduction compared for 2006 only

Conclusions

The objectives of this study were to evaluate effectiveness of BMPs implemented in the CLW (1995-2006) for reduceing flow, sediment yield, and total phosphorus transport to the various reaches of the CLW. This study evaluated effectiveness of three major BMPs: (i) agricultural waste, (ii) repair failing septic systems, and (iii) increase conservation reserve programs (CRP).

Several conclusions can be drawn from the SWAT model simulated results of this study including: (i) applying agricultural waste BMPs and repair failing septic systems reduced total phosphorus losses from the watershed, (ii) Applying agricultural waste BMPs could reduced total phosphorus losses (1 to 6 times) more than repair failing septic systems, (iii) CRP land conversion reduced flow, sediment, and total phosphorus transport from the watershed. The CRP land conversion BMP was particularly effective in reducing both sediment and total phosphorus transport from the watershed. We conclude that CRP conversion is most effective BMP evaluated in this study. Future studies will compare individual and combined effects of other BMPs, such as terracing, and no-till practices on water quality.

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